METHOD AND APPARATUS FOR PROVIDING VARIABLE ATTENUATION
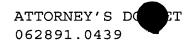TO DATA SIGNALS IN AN XDSL FREQUENCY RANGE

TECHNICAL FIELD OF THE INVENTION

This invention relates in general to data communication, and more particularly to a method and apparatus for providing variable attenuation to data

5 signals in an xDSL frequency range.

BACKGROUND OF THE INVENTION

The recent growth of the Internet has increased the demand for additional bandwidth. Digital subscriber line (xDSL) technology meets the demand by providing higher

5   bandwidth data service over existing twisted pair telephone lines. xDSL technology achieves higher data transmission rates by taking advantage of unused frequencies, which are significantly higher than voice band frequencies, on existing twisted pair lines.
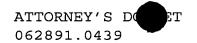
10   xDSL technology, however, is limited because signals cannot be transmitted over long distances without losing signal strength. Due to this limitation, subscribers located closer to the data service provider typically achieve higher data transmission rates than subscribers

15   located further away. Data transmission rates to subscribers located a short distance from the data service provider, however, can also be affected by other conditions, such as noise on the digital signals or intermodulation within the data transmission bands.
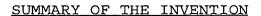
SUMMARY OF THE INVENTION

In accordance with the teachings of the present invention, the disadvantages and problems associated with xDSL data transmission have been substantially reduced or
5   eliminated. In particular, an attenuation device is disclosed that provides variable attenuation for data signals in an xDSL frequency range without interfering with telephone services to a subscriber premises.

In accordance with one embodiment of the present
10   invention, an attenuation device includes a resistive circuit that couples to a tip wire and a ring wire of a twisted pair line. A capacitive circuit couples to the resistive circuit. The capacitive circuit permits normal operation of telephone services at a subscriber premises
15   and provides variable attenuation for data signals in an xDSL frequency range.

In accordance with another embodiment of the present invention, an xDSL communications device includes a selector located in a housing and an attenuation device
20   coupled to the selector within the housing. The attenuation device includes a resistive circuit having a first end and a second end. Capacitive circuits couple to the first end of the resistive circuit and permit normal operation of telephone services at a subscriber
25   premises. The capacitive circuits include resistive elements coupled in parallel to capacitive elements. A variable gain amplifier is located in the housing and couples to the selector and the second end of the resistive circuit. The gain of the amplifier is

regulated by a gain control circuit, which in turn is controlled by a processor coupled to the gain control circuit. The communications device transmits and receives data signals over a twisted pair line through a

5   line interface coupled to the selector and the capacitive circuits.

In accordance with a further embodiment of the present invention, a method for improving the performance of an xDSL modem includes filtering telephone signals

10   received from a remote location over a twisted pair line. First data signals in a transmit frequency band are received from the xDSL modem and second data signals in a receive frequency band are received from the remote location through capacitive coupling. The first and

15   second data signals are attenuated and the amount of attenuation decreases as frequency increases from the first data signals in the transmit frequency band while the amount of attenuation remains substantially consistent for the second data signals in the receive

20   frequency band.

Important technical advantages of certain embodiments of the present invention include an attenuation device that increases the training rate of an xDSL communications device by providing attenuation for

25   data signals received by or transmitted from an xDSL communications device. Data transmission rates in the xDSL communications device may be reduced because a signal is over-amplified and the xDSL communications device cannot identify the signal due to excessive noise

injected on twisted pair telephone lines. Attenuation
provided by the attenuation device may eliminate the
noise injected on the telephone lines and may allow the
xDSL communications device to train at higher data

5   transmission rates.

        Another important technical advantage of certain
embodiments of the present invention includes an
attenuation device that provides a decreasing amount of
attenuation as the frequency of a data signal increases

10   in an upstream frequency band. In conventional xDSL
systems, injected noise on twisted pair telephone lines
distorts lower frequency signals more than higher
frequency signals. The attenuation device provides a
larger amount of attenuation for the lower frequency

15   signals and thus, reduces or eliminates the injected
noise.

        An additional important technical advantage of
certain embodiments of the present invention includes an
attenuation device that, when connected to a premises,

20   allows normal operation of telephone services at the
premises. The attenuation device contains capacitive
elements that block low frequency telephone signals and
prevent them from being attenuated. The attenuation
device, therefore, may be added without affecting the

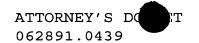25   integrity of the telephone network at the premises.

        A further important technical advantage of certain
embodiments of the present invention includes an
attenuation device that models different lengths of
twisted pair telephone wire. In one embodiment, the

attenuation device contains numerous H-pad attenuators
that model different lengths of twisted pair wire. The
attenuation provides greater flexibility because one
attenuation device may be adapted for a range of twisted

5   pair line lengths. Other technical advantages will be
readily apparent to one skilled in the art from the
following figures, descriptions, and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 illustrates one embodiment of an attenuation device in an xDSL communication system according to the teachings of the present invention;

5   FIGURE 2 illustrates in more detail the attenuation device coupled to an xDSL modem;

FIGURE 3 illustrates in more detail the attenuation device integrated in the xDSL modem;

FIGURE 4 illustrates a circuit diagram of the

10   attenuation device; and

FIGURE 5 illustrates a graph of the attenuation provided by the attenuation device over a frequency range.

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DETAILED DESCRIPTION OF THE INVENTION

       FIGURE 1 illustrates an xDSL communication system 1
that transmits data information in the form of signals
between two modems 2 and 4. Modem 2 is coupled to modem

5   4 by a subscriber line 6. Subscriber line 6 supports
simultaneous telephone and data service using twisted
pair line. Telephone 8 is coupled to subscriber line 6
and computer 10 is coupled to modem 4. Attenuation
device 12 is coupled between subscriber line 6 and modem

10   4.

       Subscriber line 6 couples modem 4 to modem 2.
Subscriber line 6 comprises twisted pair wiring, which is
commonly installed at the subscriber premises and as the
local loop in many public switched telephone networks

15   (PSTNs). Subscriber line 6 may be unshielded twisted
pair (UTP), shielded twisted pair (STP), or other
suitable type or category of twisted pair wiring made of
copper or any other suitable conductive material. In a
particular embodiment, subscriber line 6 includes tip and

20   ring conductors.

       Telephone 8 is a traditional telephone transceiver,
a cordless telephone transceiver, or any other device
suitable for allowing voice communication over subscriber
line 6. In one embodiment, telephone 8 operates with a

25   plain old telephone system (POTS) utilizing a frequency
band between 0 H_z and 4 KH_z. Telephone 8 may couple to
subscriber line 6 using an appropriate passive or active
splitter to isolate telephone signals from xDSL signals.
Computer 10 is a mainframe device, mini-frame device,

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server, desktop personal computer, notebook personal

computer, or other suitable computing device.

In one embodiment, modem 4 is an external xDSL modem

and couples to computer 10. Modem 4 communicates data to

5   and from computer 10 using subscriber line 6. In another

embodiment, modem 4 is an internal xDSL modem that is

located in computer 10 and communicates data to and from

computer 10. Modem 4 couples to other components of

computer 10 using a Peripheral Component Interconnect

10   (PCI) bus, an Industrial Standard Architecture (ISA) bus,

a Personal Computer Memory Card International Association

(PCMCIA) interface, or any other suitable technology that
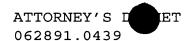
provides input/output capability to computer 10.

Modems 2 and 4 transmit and receive data using any

15   suitable digital subscriber line technology, referred to

generally as xDSL. Modems 2 and 4 may support Ethernet,

Fast Ethernet, V.35 data protocol, frame relay,

asynchronous transfer mode (ATM), switched multi-megabit

data service (SMDS), high-level data link control (HDLC),

20   serial line Internet protocol (SLIP), point-to-point

protocol (PPP), transmission control protocol/Internet

protocol (TCP/IP), or any other appropriate protocol,

collectively referred to as digital protocol. In

general, modems 2 and 4 translate information between the

25   communication protocol, such as xDSL, and the digital

protocol. System 1 contemplates any suitable arrangement

of protocol or other communication techniques implemented

in hardware and/or software that allows modems 2 and 4 to

communicate data using subscriber line 6.

Modems 2 and 4 transmit data information over
subscriber line 6 using asymmetric digital subscriber
line (ADSL), ADSL lite, rate-adaptive digital subscriber
line (R-ADSL), high bit-rate digital subscriber line

5   (HDSL), single-line digital subscriber line (SDSL), very
high bit-rate digital subscriber line (VDSL) or any other
suitable technology that allows high rate data service
over twisted pair wiring. All of these technologies are
referred to collectively as xDSL or communication
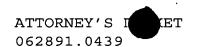
10 protocol.

xDSL technology provides data service using existing
twisted pair wiring without interrupting normal telephone
service. This is accomplished by a separation technique,
such as frequency division multiplexing (FDM). FDM

15 creates two different bands of frequencies, one for
upstream data and the other for downstream data. Both
bands may be divided by time division multiplexing (TDM)
into one or more high-speed channels and one or more low-
speed channels. FDM operates to separate frequencies

20 that provide telephone service from those frequencies
that provide data service. Telephone signals typically
have frequencies ranging approximately from 0 H_z to 4 KH_z
while data signals used for xDSL communication have
frequencies ranging from approximately 25 KH_z to 1 MH_z or

25 higher. Dynamic noise cancellation techniques and a
guard band located between the telephone frequency range
and the data frequency range ensure reliable and
simultaneous access to data and phone service over
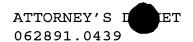subscriber line 6. For example, a subscriber at the

subscriber premises may simultaneously engage in both a data communication session using computer 10 and a voice conversation using telephone 8.

In one embodiment, modems 2 and 4 support xDSL
5   communication over subscriber line 6 using techniques, such as discrete multitone (DMT) modulation, that comply with ANSI standard T1.413. DMT modulation discretely divides the available frequencies on subscriber line 6 into subchannels or tones. Incoming data signals are
10   broken down into a variety of bits and distributed to a specific combination of subchannels based on the subchannels' ability to carry the transmission. In another embodiment, xDSL communication over subscriber line 6 may be performed using a carrier-less amplitude
15   phase (CAP) modulation technique. CAP modulation generates a modulated wave that carries amplitude and phase state changes by storing parts of a modulated message signal in memory and then reassembling the parts in the modulated wave. In further embodiments, any other
20   suitable modulation technique may be used to support xDSL communication over subscriber line 6.

In an xDSL communication system using ADSL, data received by the end-user, generally referred to as downstream data, is transmitted at a higher rate than
25   data transmitted by the end-user, generally referred to as upstream data. The different transmission rates for upstream and downstream data allow for high bandwidth communication for information being downloaded by the end-user, while still providing lower bandwidth

communication for information being uploaded by the end-
user. ADSL communication is well adapted for
applications, such as video-on-demand, multimedia, and
Internet access, which transfer large volumes of

5   information to a modem located at a subscriber premises
in response to shorter requests for information to a
modem located at a remote location. Typical downstream
data transmission rates range approximately from 256 Kbps
to 4 Mbps and typical upstream rates are approximately

10   between 128 Kbps to 1.5 Mbps. The maximum data
transmission rates are typically achieved at distances of
up to approximately 10,000 to 12,000 feet using a
standard 24-gauge twisted pair wire. xDSL transmission
rates also depend on the specific xDSL technology used,

15   the quality and length of subscriber line 6, and the
contribution of noise and distortion from other
components throughout the system. Although system 1 has
been described in reference to ADSL, any other suitable
xDSL communication standard may be used.

20   In one embodiment, attenuation device 12 couples
between modem 4 and subscriber line 6. In alternative
embodiments, attenuation device 12 may only be coupled to
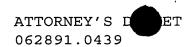modem 2 or may be coupled to both modems 2 and 4.
Attenuation device 12 filters out telephone signals

25   received from subscriber line 6 and attenuates data
signals received from or transmitted to remote modem 2
via subscriber line 6. More specifically, attenuation
device 12 includes capacitive circuits that block low
frequency telephone signals from passing through

resistive sections of attenuation device 12 but allow
higher frequency data signals to pass through resistive
sections of attenuation device 12.

In normal operation of telephone services at a
5   premises, network equipment coupled to subscriber line 6
can detect two operating states: on-hook and off-hook.
In the on-hook state, the tip and ring wires of
subscriber line 6 form an open circuit and the resistance
detected by network equipment coupled to subscriber line
10 6 is above a predetermined threshold. In the off-hook
state, the tip and ring wires of subscriber line 6 form a
closed circuit and the resistance detected by network
equipment coupled to subscriber line 6 is below the
predetermined threshold. When the on-hook state is
15 detected by the network equipment, the telephone network
at a subscriber premises may receive an incoming
telephone call from subscriber line 6 and when the off-
hook state is detected, the telephone network at the
premises cannot receive an incoming call because the
20 network is busy. Without the capacitive circuits, the
resistive section of attenuation device 12 would cause
the resistance of subscriber line 6 to always be below
the predetermined threshold, thus representing an off-
hook state. The capacitive circuits, therefore, permit
25 normal operation of telephone services at the subscriber
premises by preventing network equipment coupled to
subscriber line 6 from detecting an artificial off-hook
state at the subscriber premises.

FIGURE 2 illustrates, in more detail, attenuation
device 12 coupled to modem 4. Modem 4 comprises a
receive amplifier 14, a transmit amplifier 16, an
automatic gain control (AGC) system 18, a processor 20,

5   and memory 22 coupled to processor 20. Attenuation
device 12 couples between subscriber line 6 and the input
of receive amplifier 14 and the output of transmit
amplifier 16. As in FIGURE 1, telephone 8 couples to
subscriber line 6 and provides for voice communication

10   using subscriber line 6.

In FIGURES 2 and 3, processor 20 may be a
microprocessor, a microcontroller, a digital signal
processor (DSP) or any other digital circuitry configured
to process information. Processor 20 may perform data

15   modulation, error recovery, channel separation, echo
estimation and cancellation, encoding and decoding
operations, training sessions and any other signal
processing and communication tasks.

Receive amplifier 14 and transmit amplifier 16 may

20   be variable gain circuits having a variety of components
that process data signals for presentation to processor
20. For example, the components forming receive
amplifier 14 and transmit amplifier 16 may include
components that provide gain in order to bring the data

25   signal to a level that is compatible with processor 20.
In one embodiment, receive amplifier 14 and transmit
amplifier 16 may comprise a plurality of gain stages.
AGC 18 may control all stages of receive amplifier 14 and
transmit amplifier 16. In an alternative embodiment, one

stage of receive amplifier 14 and transmit amplifier 16
may provide a substantially consistent gain to the
transmitted or received data signal. In this particular
embodiment, AGC 18 may not control at least one stage of
5   receive amplifier 14 and transmit amplifier 16.

Memory 22, coupled to processor 20, may store data
signal profile information such as coefficients used in
CAP, DMT, or any other suitable modulation techniques,
maximum data transmission rates for upstream and
10   downstream data, margins, and other information that may
reflect the physical or electrical properties of
subscriber line 6. Margins may represent the difference
between a current or expected signal strength and a
minimum signal strength needed to maintain communication
15   at the chosen data transmission rate over subscriber line
6.

Memory 22 may also store a training algorithm used
by modem 4 to achieve maximum data transmission rates.
Processor 20 may execute the training algorithm when a
20   communications channel is being established between
modems 2 and 4. By using the training algorithm stored
in memory 22, processor 20 may attempt to select the
fastest transmission rates for data signals being
communicated in the upstream and downstream directions.

25   Processor 20 directs handshaking operations and
negotiates rates for data transmission between modems 2
and 4 when executing the training algorithm stored in
memory 22. During a training session, processor 20
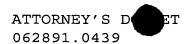attempts to train modem 4 at the highest possible data

transmission rates.   If the attempt fails because processor 20 cannot recognize the data signal due to excessive noise, processor 20 lowers the data transmission rate until it successfully establishes a

5   connection between modems 2 and 4.

Memory 22 also stores information needed by processor 20 to execute the training algorithm.   This information may include the baud rate of modem 4, the signal quality of the received or transmitted data

10   signals, the gains of receive amplifier 14 and transmit amplifier 16, the desired margin, and any other information that characterizes subscriber line 6 and the appropriate communication parameters for modem 4.   The baud rate identifies different modulation rates of data

15   signals communicated between modems 2 and 4.   The signal quality describes the quality of the signals transmitted between modems 2 and 4, where lower signal qualities typically represent higher-quality connections.   The gain of receive amplifier 14 or transmit amplifier 16

20   identifies the strength of the data signal received or transmitted by modem 4 and how much that signal should be amplified.   The desired margin describes the ability of modem 4 to correct errors during data transfers before the errors excessively affect the data transmission rate.
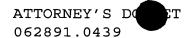
25   Processor 20 begins a training session of a signal received from modem 2 over subscriber line 6 by determining the quality or characteristics of the received signals.   In one embodiment, AGC 18 measures the signal strength of the data signal and communicates the
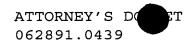
measured signal strength to processor 20. Processor 20
compares the measured signal strength with profile
information stored in memory 22 in order to determine if
the data signal requires any amplification. If processor

5   20 determines that the data signal should be amplified,
processor 20 calculates the amplification desired and
communicates the appropriate information to AGC 18. AGC
18 then adapts the gain of receive amplifier 14 in
accordance with the level of the measured signal strength

10   and the calculated amplification provided by processor
20. For example, if the measured signal strength is
below a first level, AGC 18 may increase the gain of
receive amplifier 14. If the measured signal strength is
above the first level but below a second level, AGC 18

15   may decrease the gain of receive amplifier 14
accordingly. If the measured signal strength is above
the second level, AGC 18 eliminates the gain of receive
amplifier 14. In one embodiment, AGC 18 controls all
stages of amplification in receive amplifier 14 and

20   transmit amplifier 16 and reduces the gain of receive
amplifier 14 and transmit amplifier 16 to unity if the
measured signal strength is above the second level. In
another embodiment, AGC 18 has no control over the final
stage of receive amplifier 14 and transmit amplifier 16

25   and reduces the gain of receive amplifier 14 and transmit
amplifier 16 to the value of the substantially consistent
gain provided by at least one stage. Although the
operation of modem 4 has been described in reference to a
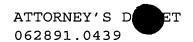data signal received by modem 4, it will be recognized

that the same principles apply to signals transmitted by modem 4 to modem 2.

Although AGC 18 may reduce or eliminate the gains of receive amplifier 14 and transmit amplifier 16, data

5 signals received from a data service provider located a short distance, e.g., less than 5,000 feet, from the subscriber premises may have a signal strength above the second level. Data signals having signal strengths above the second level may inject excessive noise into either

10 the upstream or downstream frequency bands. In one embodiment, if a data signal is received from modem 2 at modem 4 and the measured signal strength is above the first level, AGC 18 reduces the gain of receive amplifier 14 in an attempt to eliminate noise. If the noise is not

15 completely eliminated by reducing the gain of receive amplifier 14 and modem 4 cannot identify the data signal, processor 20 causes modem 4 to train at a lower rate until the data signal can be identified. Using amplifiers with more sensitive dynamic ranges may reduce

20 the noise on the data signal so that it can be identified without reducing the data transmission rate. Adding sensitivity to receive amplifier 14 and transmit amplifier 16 in modem 4, however, requires that modem 4 be redesigned with complex and expensive circuitry and is

25 a costly option because the subscriber typically must purchase a new modem.

Attenuation device 12 allows modem 4 to train at higher data transmission rates by filtering out telephone signals and attenuating data signals received and

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transmitted by modem 2 using subscriber line 6. Although

extra attenuation in twisted pair wiring is generally not

desirable because data signals are attenuated as they

travel through subscriber line 6, some problems

5   associated with xDSL communication systems may be solved

by using attenuation device 12. For example, subscribers

located short distances from a data service provider

location may experience reduced data transmission rates

due to excessive noise on received data signals,

10   intermodulation between the upstream and downstream

frequency bands, non-linear amplifier operation, or the

use of a modem having a insufficient dynamic range. When

receive amplifier 14 or transmit amplifier 16 operates in

a non-linear mode, the data signals may be clipped so

15   that processor 20 cannot distinguish injected noise from

the data signals.

     Attenuation device 12 operates to set the dynamic

ranges of receive amplifier 14 and transmit amplifier 16

based on the strength of the data signals and therefore,

20   may increase the dynamic ranges of receive amplifier 14

and transmit amplifier 16 in modem 4 for a given length

of subscriber line 6. As described previously,

attenuation device 12 includes capacitive circuits that

operate to filter telephone signals but permit data

25   signals to pass through a resistive section. The

resistive section of attenuation device 12 reduces noise
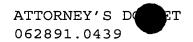
on a data signal by reducing the signal strength.

Processor 20 may identify the data signal without

reducing the data transmission rate because the noise is

reduced to a level where the processor may distinguish noise from the data signal. Also, attenuation device 12 is a low cost option because no redesign of either modems 2 or 4 is required. A subscriber at the subscriber

5   premises may install attenuation device 12 between subscriber line 6 and modem 4 without rewiring the subscriber premises or replacing modem 4.
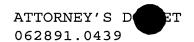
Attenuation device 12 coupled to modem 4 may also improve the performance of the receive amplifier 14 and

10   increase the dynamic range of modem 2. When transmitting a data signal from modem 4 to modem 2, processor 20 may determine that the data signal should be amplified in order to be transmitted through subscriber line 6. In one embodiment, however, modem 2 may be located a short

15   distance from modem 4. At this distance, the data signal may not require the amount of amplification provided by transmit amplifier 16 of modem 4. Modem 2 may receive the over-amplified data signal and may cause modem 4 to train at a lower rate because a receive amplifier in

20   modem 2 may not be able to identify the data signal. Attenuation device 12 may reduce the strength of the data signal and thus, allow modem 2 to identify the data signal without having to reduce the data transmission rate.   In order to reduce or eliminate noise in the

25   data signal, xDSL modems require amplifiers with sensitive dynamic ranges. Adding more sensitivity to the dynamic range of receive amplifier 14 and transmit amplifier 16 would require modem 4 to be redesigned. Attenuation device 12 may be retrofit to any xDSL

communications system by coupling attenuation device 12

between subscriber line 6 and modem 4.   In one

embodiment, attenuation device 12 may be located in a

housing having two line interfaces.   Each interface may

5   be coupled to one end of attenuation device 12.   One line

interface may be coupled to modem 4 and the other line

interface may be coupled to a standard RJ-11 wall-jack

located at a premises.   The wall-jack operates to couple

attenuation device 12 to a telephone network at the

10   premises.   The ability to retrofit the attenuation device

to any xDSL communications device at any subscriber

premises reduces the cost for a subscriber.   If the

subscriber experiences reduced data transmission rates,

the subscriber does not have to purchase another modem 4

15   with a more sensitive dynamic range.   The subscriber may

purchase attenuation device 12 and couple it to modem 4.

With the addition of attenuation device 12, modem 4 may

train at higher data transmission rates and may achieve

maximum data transmission rates for a given length of
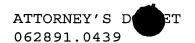
20   subscriber line 6.

Attenuation device 12 also operates to model a

length of subscriber line 6.   As will be described in

more detail below, attenuation device 12 includes a

resistive section that contains more than one resistive

25   element.   The values of the resistive elements determine

the length of wire modeled by attenuation device 12.

Attenuation device 12 may be designed to model different

lengths of twisted pair wire and may be added to system 1

to provide attenuation that reduces noise on the data

signals. In one embodiment, attenuation device 12

includes a resistive section containing variable

resistors. The resistance of each resistor in

attenuation device 12 may be changed based on a variety

5   of factors. In another embodiment, attenuation device

may include more than one resistive section, where each

resistive section represents a different length of

subscriber line 6. A hardware and/or software selector,

switch, controller, or other selection technique

10   (generally referred to as selector) may control which

resistive section is used to attenuate the data signal.

FIGURE 3 illustrates attenuation device integrated

with the components inside the housing of modem 5.

Similar to modem 4 illustrated in FIGURE 2, modem 5

15   comprises receive amplifier 14, transmit amplifier 16,

AGC 18, processor 20 and memory 22. Modem 5 also

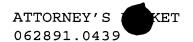includes attenuation device 12 and selector 24.

Processor 20 may control selector 24 based on the

measured signal strength of the data signal. In one

20   embodiment, when modem 5 receives a data signal from

modem 2, selector 24 is closed allowing the data signal

to bypass attenuation device 12. If modem 5 identifies

the data signal, processor 20 keeps selector 24 closed so

that the data signal is not attenuated. If modem 5

25   cannot identify the data signal and the gain of receive

amplifier 14 has been reduced to its lowest value,

processor 20 opens selector 24. The resistive section in

attenuation device 12 attenuates the data signal. In an

alternative embodiment, modem 5 contains more than one

attenuation device 12 and more than one selector 24

associated with each attenuation device 12. Processor 20

controls selector 24 and selects one of attenuation

devices 12 based on the measured signal strength of the

5   data signal. In order to choose the appropriate

attenuation device 12, memory 22 may contain a table

including multiple signal strengths, the amount of

attenuation associated with each signal strength and the

length of twisted pair wiring that corresponds to the

10   desired attenuation. After measuring the signal strength

of the data signal, processor 20 may access the table

stored in memory 22. Processor 20 may compare the

measured signal strength with the signal strengths

contained in the table. If the data signal should be

15   amplified according to the values in the table, processor

20 may close selectors 24 associated with attenuation

devices 12 so that the data signal bypasses the

attenuation devices 12. The measured signal strength may

then be communicated to AGC 18 so that AGC 18 may cause

20   receive amplifier 14 to provide the desired amount of

gain to the data signal. If the data signal does not

need amplification and the signal strength has been

determined to be above the second level, processor 20

selects the appropriate selector 24 to open so that the

25   data signal passes through attenuation device 12 that is

able to provide the required amount of attenuation.

Although the operation of selector 24 has been described

in reference to a data signal received by modem 5, it

will be recognized that the same principles apply to

24

signals transmitted by modem 5 to modem 2. Furthermore,
it will be recognized that selector 24 may be implemented
in hardware and/or software.

          Integrating attenuation device 12 into modem 5 may
5   also provide advantages for the subscriber. Although the
subscriber may have to purchase another modem, the cost
of the modem may be much less than a modem using complex
circuitry to increase the dynamic ranges of receive
amplifier 14 and transmit amplifier 16. Furthermore,
10   integrating attenuation device 12 in modem 5 gives modem
5 greater flexibility in choosing when to attenuate the
data signal and how much attenuation to provide.

          FIGURE 4 illustrates a circuit diagram of
attenuation device 12. Attenuation device 12 includes
15   capacitive circuits 27, 29, 31 and 33 and resistive
section 35. Capacitive circuits 27 and 29 couple to a
first end of resistive section 35 and capacitive circuits
31 and 33 couple to a second end of resistive section 35.
By coupling capacitive circuits 27, 29, 31 and 33 to both
20   ends of resistive section 35, attenuation device 12 may
be interchangeable such that either capacitive circuits
27 and 29 may couple to subscriber line 6 or capacitive
circuits 31 and 33 may couple to subscriber line 6. In
an alternative embodiment, attenuation device 12 may
25   include capacitive circuits 27 and 29 and resistive
section 35. Capacitive circuits 27 and 29 may couple
between the first end of resistive section 35 and
subscriber line 6. Capacitive circuits 27, 29, 31 and 33
function to block ring voltage from subscriber line 6 and

protect resistive section 35 from the ring voltage. In
one embodiment, resistive section 29 is an H-pad
attenuator. The H-pad attenuator allows bi-directional
communication of data signals and provides linear

5   attenuation to data signals received from subscriber line
6 or transmitted by modem 4.

Capacitive circuits 27, 29, 31 and 33 include
capacitive elements 26 and resistive elements 28.
Capacitive circuits 27 and 31 couple to the tip wire of

10   subscriber line 6 and capacitive circuits 29 and 33
couple to the ring wire of subscriber line 6. Capacitive
elements 26 couple to the tip and ring wires and
resistive elements 28 couple in parallel to capacitive
elements 26. Capacitive elements 26 function to block

15   low frequency telephone signals from passing through
resistive section 35 and resistive elements 28 function
to protect capacitive elements 26 from any voltage
division problems. Resistive section 35 comprises
resistive elements 30, 32, 34, 36 and 38. Resistive

20   element 30 couples in series between capacitive circuit
27 and resistive element 34 on the tip wire of subscriber
line 6 and resistive element 34 further couples in series
to capacitive circuit 31. Resistive element 32 couples
in series between capacitive circuit 29 and resistive

25   element 36 on the ring wire of subscriber line 6 and
resistive element 36 further couples in series to
capacitive circuit 33. Resistive element 38 couples in
series to resistive elements 30, 32, 34 and 36 and is
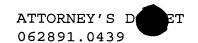located between the tip and ring wires of subscriber line

6.   Since resistors 30, 32, 34 and 36 couple to both ends
of attenuation device 12, bi-directional communication is
possible.   For example, attenuation device 12 may
attenuate data signals received by modem 4 through

5   subscriber line 6 and may attenuate data signals
transmitted from modem 4.

In one embodiment, capacitive elements 26 are 1 μF
capacitors and resistive elements 28 are 1 M resistors.
In a particular embodiment, resistive section 35 models

10   2,000 feet of subscriber line 6 wire.   Resistive elements
30, 32, 34 and 36 are 9   resistors and resistive element
38 is a 100   resistor.   Resistive element 38 operates to
match the impedance of subscriber line 6.   At frequencies
lower than 25 KH$_z$, capacitive elements 26 block signals

15   from passing through resistive section 35 and thus, from
being attenuated.   At frequencies higher than 25 KH$_z$,
however, capacitive elements 26 allow signals to pass
through resistive section 35 and to be attenuated.

Although attenuation device 12 has been described in

20   reference to modem 4, it will be recognized that
attenuation device 12 may be coupled to modem 2 and
perform the same functions.   Further, attenuation device
12 may be coupled to both modems 2 and 4 so that noise on
the data signals can be reduced or eliminated at both the

25   source and the destination for the data signals.

FIGURE 5 shows the amount of attenuation provided by
attenuation device 12 to telephone signals in POTS
frequency band 40 and to data signals in xDSL frequency
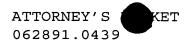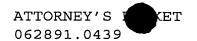band 44.   Specifically, the graph is a plot of frequency

on the horizontal axis and attenuation on the vertical
axis. POTS frequency band 40 generally extends from
approximately 0 H_z to approximately 4 KH_z. xDSL frequency
band 44 is comprised of upstream frequency band 46 and

5   downstream frequency band 48. In one embodiment, signals
in upstream frequency band 46 are transmitted from a
subscriber to a data service provider and signals in
downstream frequency band 48 are received by the
subscriber from the data service provider. Upstream

10   frequency band 46 generally extends from approximately 25
KH_z to approximately 270 KH_z and downstream frequency band
48 generally extends from approximately 270 KH_z to
approximately 1 MH_z or higher. The upper boundary of
downstream frequency band 48 varies depending on the

15   particular xDSL technology used. A guard band 42
provides some margin of separation between POTS frequency
band 40 and upstream frequency band 46, which may provide
noise and cross-talk immunity for signals in POTS
frequency band 40 and upstream frequency band 46.

20   As shown in FIGURES 4 and 5, telephone signals in
POTS frequency band 40 are blocked from passing through
resistive section 35 by capacitive elements 26. Together
capacitive elements 26 and resistive elements 28 form a
high pass filter, which filters out low frequency

25   telephone signals in POTS frequency band 40 and allows
higher frequency data signals in xDSL frequency band 44
to pass through attenuation device 12. As frequencies
increase, the amount of attenuation provided by
attenuation device 12 decreases. In the upstream

frequency band 46, the amount of attenuation decreases as the frequency of the data signal increases. Injected noise on subscriber line 6 may cause lower frequency signals in upstream frequency band 46 to be over-

5   amplified. Attenuation device 12 reduces or eliminates the noise by providing a greater amount of attenuation to the lower frequency signals. In the downstream frequency band 48, the amount of attenuation is substantially consistent for all frequencies because injected noise on

10   subscriber line 6 may not distort the higher frequency signals as much as it distorts the lower frequency signals. Although FIGURE 5 shows the substantially consistent amount of attenuation as 5 dB, this may be varied by changing the values of resistive elements 30,

15   32, 34 and 36. If the values of resistive elements 30, 32, 34 and 36 are decreased, the amount of attenuation provided by attenuation device 12 in downstream frequency band 48 decreases and if the values are increased, the amount of attenuation also increases.

20   Although the present invention has been described in detail, it should be understood that various changes, substitutions, and alterations can be made hereto without departing from the spirit and scope of the invention as defined by the appended claims.